Binding Energy, Fusion and Fission

When matter meets the corresponding anti-matter, it annihilates- the mass changes into gamma rays.

According to Einstein's theory of relativity

$E=mc^2$

the energy released equals the mass annihilated times the speed of light in a vacuum squared

eg. an electron and a positron annihilate. How much energy is given off?

$E=mc^2$
$c=3.0 \times 10^8 m/s$
mass of an electron = $9.11 \times 10^{-31} kg$ = mass of a positron

$E=(9.11 \times 10^{-31} kg + 9.11 \times 10^{-31} kg)(3.0 \times 10^8 m/s)^2$
$1.6 \times 10^{-13} J$

For small energies, we sometimes use the unit

megaelectron volt, MeV = 1.6×10^{-13}J

so the energy given off = 1.0 MeV

Binding Energy

mass of a proton = 1.007825u
mass of a neutron = 1.008665u
u is the atomic mass unit = 1.6605×10^{-27}kg = 1/12 the mass of carbon 12 nucleus

the mass of the nucleus is less than the mass of protons and neutrons added together. What's the deal? Where does the mass go?

eg. helium 4 has a mass of 4.002603u

the mass of 2 protons and 2 neutrons is:
2(1.007825u)+2(1.008665u)= 4.032980u

The difference between the masses is the mass defect = 4.032980-4.002603=0.030377 u

Where did the mass go?

The mass was released as energy during the

formation of the nucleus in nuclear fusion in stars (and big bang, and supernovae)

This energy is called the binding energy. It is also the amount of energy required to pull the nucleus apart.

$E=mc^2$ the energy released when 1 u is changed into energy is
$= 1.6605 \times 10^{-27}kg \times (2.9979 \times 10^8 m/s)^2$
$= 1.4923 \times 10^{-12}$ J
convert into mega electron volts
1.4923×10^{-12} J $(1MeV/1.6022 \times 10^{-13}$ J)
= 931.49 MeV energy per u of mass

so the binding energy of Helium 4
= mass defect x 931.49 MeV/u
= 0.030377u x 931.49 MeV/u
= 28.662 MeV

the more binding energy per nucleon, the more stable the nucleus - graph p641 - iron 56 or nickel 62 are the most stable nuclei

p642 q1-4, p643 1.1-1.4

10 minutes then Fission and Fusion

Fusion:
2 nuclei combine together to form a bigger nucleus.

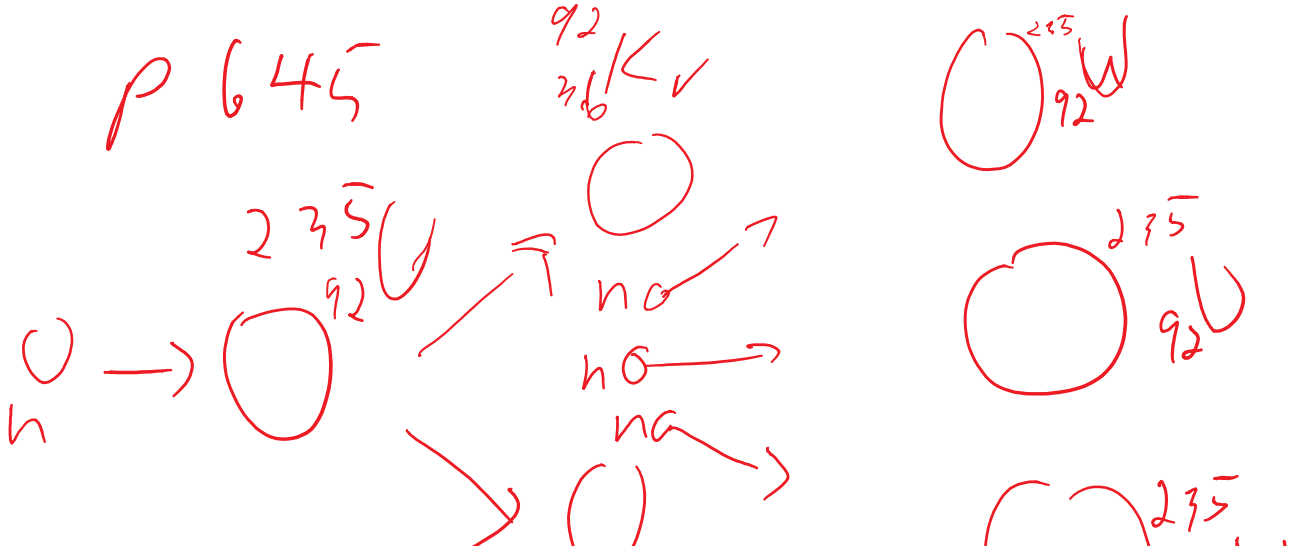
eg. in the sun hydrogen combines to form helium.

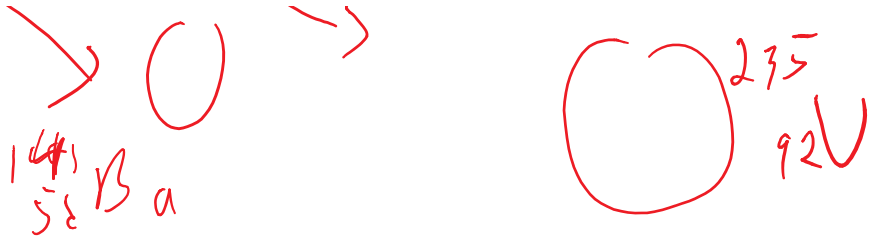
4 hydrogens combine to form Helium 4 (after 2 beta positive decays)

Lots of energy is released.

Fission:
When a big nucleus breaks apart into 2 smaller daughter nuclei of about the same size.
Lots of energy is also released.

eg. uranium 235 gets hit with a slow neutron and breaks apart into 2 nuclei and more neutrons.





A chain reaction is when the released neutrons hit more uranium to continue the reaction.

Critical mass is the mass of uranium required for a chain reaction to occur.

The strong force holds the nucleus together, and depends on the number of protons and neutrons.

uranium 238 is stable, even if you hit it with a neutron. It actually transmutes into plutonium after 2 beta minus decays.

the results of fission are highly radioactive, so radioactive waste to dispose of

next class - nuclear reactors and bombs and review for test Monday June 6th on
ch 18,19, 30, 31

p652 q9,10, mass deuterium = 2.0140 u

mass of tritium = 3.016049u
mass of Helium 4 = 4.002603u
p655 q 11, 15, 20, 23